GEOLOGICAL DEVELOPMENT OF KANSAS.

By Lyman C. Wooster.

THE RAIN OF PLANETESIMALS.

THE nebular hypothesis of Kant and Swedenborg has failed to meet the tests applied by modern men of science, and soon will be remembered as being merely one of the dreams of philosophy. Finding that the nebular hypothesis is unsupported by scientific data in many vital parts, the writers of the later scientific texts have substituted the planetesimal hypothesis of Chamberlin, believing that it gives a truer explanation of the development of the earth. According to this hypothesis the earth began as one of several nuclei in an arm of a spiral nebula, a form of nebula very common in the heavens at the present time, and has slowly reached her present size through the accretion of myriads of small planetesimals which were drawn in from the neighboring regions of the nebula.

As the planetesimals accumulated the pressure within the young planet eventually became so great that many absorbed gases were forced from their enclosing cavities and driven to the surface. When the earth had reached nearly her present size the escaping nitrogen and oxygen were recaptured by gravity and remained as an atmosphere; heated hydrogen and oxygen united to form water vapor somewhere in the earth's crust, and on escaping into the atmosphere it cooled and condensed into rain, which returned to the earth and filled up all the depressions on her surface and became the seas and oceans; some of the oxygen picked up carbon and became carbon-dioxide gas, which escaped into the atmosphere through fissures or volcanoes or bubbled up through the water and became one of the greatest agents in the reconstruction of the earth's surface and one of the substances of the highest importance to the future plants and animals; hydrogen and carbon also united somewhere in the interior of the earth, and possibly became the petroleum and natural gas so highly prized in the arts.

FOOTNOTE.—The limits of this paper forbid giving more than the story of the geological development of Kansas. The data in full and the scientific arrangement of these data will be found in the various reports and manuals that give the geology of the states occupying the Great Plains.

Most of the heated gases on escaping from the earth's interior made various chemical unions on reaching the cooler crust and served various uses in nature's laboratory. It has recently been learned that the water of tropical Atlantic ocean is twice as rich in oxygen at a depth of 4000 feet as at 400 feet.* This may be partly explained by regarding the crust of the earth beneath the ocean as a storehouse of oxygen.

The earth's nucleus and the planetesimals in the spiral nebula were probably cold, according to Chamberlin, but the force pulling the tiny solids towards the center of the mass became in time so great that the nucleus with the inner planetesimals became very hot under the compressing force. The surface of the earth, however, remained cold and solid, except where the molten interior poured forth through fissures and buried the crust beneath great sheets of molten lava. In the earlier history of the earth this happened so frequently and at so many places that little, if any, of the primitive crust remains at the surface.

AND HIGH LAND APPEARED.

So far as the geologist now knows, the first permanent high land to appear above the general level of the earth's crust in what is now North America arose as great mountain ranges, which (1) stretched along our Atlantic border; (2) bounded Hudson Bay on the east, south and west; (3) followed the general course of what are now the Rocky Mountains; and (4) reared aloft granite summits a little east of where are now the Sierras.

The winds and rains of a moisture-laden atmosphere and the waves of mighty seas and oceans beat upon these great mountains for fifteen or twenty million years, wearing them down and sorting and scattering debris in the seas and oceans till low-lying mountains, bordered by shallow-water sand flats and mud flats, were all that remained of the mighty ranges of granite and lava. Before these mountains were formed, life may have established itself in the seas and oceans. No one knows whence it came, but the geologist finds evidence that the waters teemed with life in the Archeozoic era; first plants, and then animals of simple organization.

While the mountains were being denuded in the Proterozoic era, worms and primitive crustaceans had their habitats on

* Science, October 17, 1913, p. 546.

the sandy bottoms or on the mud flats beyond, for the fossil remains of a few of them have been found in the indurated rocks formed of this sand and mud. Besides this direct evidence, indirect evidence of life having flourished in these seas and in fresh-water swamps on the flanks of the mountains is abundant. Beds of graphite are not uncommon, which possibly may represent the metamorphosed peat of the swamps. Beds of limestone occur, and these are usually considered as being proof of the previous existence of marine life, with skeletons of carbonate of lime. Then, too, beds of iron ore of great thickness are found interstratified with the debris of these ancient mountains. Iron ore is deposited from solution through the chemical action of organic compounds set free in the decay of the tissues of plants and animals. Probably bacteria helped in the deposition of the ore, either by causing organisms to decay or by robbing compounds of iron of all the other elements except oxygen. Copper and silver were precipitated in the same sand and mud flats and concentrated later, especially where Lake Superior now lies, possibly by the same organic reagents or by bacteria.

DRY LAND INCREASED IN AREA.

The development of the earth's topographic features has always been hastened and emphasized by periods of mountain-making. Each great range of mountains was thrown up after millions of years of comparative stability of the earth's crust. It was once believed that the great ranges of mountains came up in a few weeks, or, at most, in a few years, but it is now known that they require thousands, probably millions, of years to reach maturity.

The most ancient mountains known to the geologist, the ones already described, were forced above the general level at the close of the Archeozoic era. Then followed the fifteen or twenty million years of erosion and deposition. The interior of the earth continued to shrink very slowly because of loss of heat, while the sand, clay and calcareous mud and the various ores and organic compounds were being deposited in the seas bordering the ancient mountains, or in swamps on their flanks, till finally the accumulated stresses in the crust of the earth compelled it to wrinkle, and thus enabled it to rest on the smaller interior. The wrinkles followed lines of weakness, and these have been shown over and over again to be along ancient

mountain ranges worn nearly to the level of the sea, and especially in the belt of debris on one or the other flank, or sometimes on both flanks.

In this second yielding of the crust of the earth, this time at the close of the Proterozoic era, the ranges of the Archeozoic era were rejuvenated, the sand and mud flats on their flanks were folded, the folds were crushed together, and the sediments were metamorphosed; that is, semifused and compacted or crystallized. By this metamorphism the sand and sandstone were converted into quartzite, like that in the drift hills south of Topeka, shoved down from Minnesota and South Dakota by the Kansan glacier; and the more or less pure clay was compacted into slate and various schists. The limestone became marble, and the coal graphite.

Among the mountains of the United States that date from the close of the Archeozoic or Proterozoic eras are the Blue Ridge of Virginia, the Adirondacks of New York, the low mountains about the synclinal trough now occupied by Lake Superior, the Ozarks of Missouri, the Arbuckle and Wichita mountains of Oklahoma and some near-by mountains of Texas, various granite ranges along the belt now occupied by the Rocky Mountains, and some scattered ranges east of where now lie the Sierras.

WHERE WAS KANSAS?

During all these millenniums, and many more, Kansas lay peacefully sleeping beneath the waters of old ocean, at least what there was of her, little disturbed by the mountain-making east, south and west. Sediments were undoubtedly deposited within her borders, but of these we know nothing by observation. Of this much we are pragmatically certain, however: during the twelve million years of the Cambrian and Ordovician periods of the Paleozoic era, the winds, rains and ocean waves tore down the mountains, squeezed up at the close of the Proterozoic era and continued the work of filling up the oceans, making in them the foundations of continents and islands that appeared above the sea later, on which land life was to flourish. Of this debris Kansas undoubtedly received her share.

Before the dry land appeared, the sands were cemented into sandstone, the clays became shale, and in the deeper, clearer waters great beds of limestone were formed of the skeletons of coral polyps, crinoids, brachiopods, clams, snails, chambered

shell animals, and of the lime carbonate and silica of sea weeds and sponges.

THE THIRD PERIOD OF MOUNTAIN-MAKING.

At the close of the Ordovician period the earth's crust was again forced to wrinkle as it adapted itself to a shrinking interior, and old mountains were rejuvenated and new mountains appeared along their borders or along new lines of weakness. Among the new mountains and ridges formed at this time were the Green and Taconic mountains, and a great anticlinal ridge of especial importance to Kansas. It stretched south and southwest from what are now Put-in-bay islands of Lake Erie, along the western border of Ohio, and through Kentucky, Tennessee, Arkansas and Oklahoma. In Oklahoma the Arbuckle and Wichita mountains were rejuvenated by this geanticline, and in Missouri this great earth fold reëlevated the Ozarks and thus gave a mighty impetus to the development of Kansas.

Unknown billions of tons of clay, sand and gravel from the Ozarks and the Oklahoma mountains were poured into the Kansas basin, and myriads of ocean plants and animals added their skeletons to this debris from the mountains. At about the close of the six million years of the Silurian and Devonian periods the accumulation of sediment and the continued forcing up of the neighboring mountain regions probably brought the southeastern portion of Kansas above the level of the ocean, the first dry land in the history of the state.

The crust of the earth is never stable, especially in regions of mountain-making, and Kansas had to oscillate up and down many times before she reached her present condition of comparative stability. After being dry land for some thousands of years, southeastern Kansas sank beneath the level of the sea and received a stratum of limestone mud six or seven hundred feet thick in which were included great quantities of flint derived from plants and animals, which secrete silica (the chief mineral of flint) from sea water for their skeletons. Another oscillation and southeastern Kansas became dry land again, and the thick coating of limestone mud became hardened into rock now known as the Mississippian limestone. This time southeastern Kansas remained dry land so long that the rains wore away more than one-third of this formation. Part of the rain water followed the joints of the limestone deep into

its interior and dissolved out the rock, making great caves like those of Missouri, Kentucky and Indiana. Then Kansas sank beneath the waters of the ocean once more and the water of the crust of the earth, charged with various minerals which it had dissolved from distant portions of the limestone, surged into the caves and proceeded to fill them with flint, zinc sulfide, lead sulfide and calcite.

WHENCE CAME THE MATERIALS OF THE SHALES AND SANDSTONES OF KANSAS?

There seems to be little question that the clay and sand of the shales and sandstones of eastern Kansas came from the granites and lavas of the Ozarks of Missouri and the Arbuckle and Wichita mountains of Oklahoma. Sand, clay, carbonate of lime (calcite), and flint (silica) have little physical resemblance to granite, gneiss and lava, but chemically they are near relatives. The granites and gneisses consist chiefly of orthoclase feldspar and quartz. This feldspar is a double silicate of alumina and potash. Carbonic acid of rain water takes away the potash of the feldspar and leaves the simple silicate of alumina, which is the chief ingredient of common clay. The carbonic acid unites with the potash, making carbonate of potash. This remains in the water and eventually serves a very important function in food-making in green plants. The clay residue from the feldspar is washed away and floats out to sea, where it settles in deep water, leaving the quartz of the granite and gneiss to follow more slowly to the seashore, where the waves soon grind it into beach sand.

The feldspar of lava is quite different from that of granite and gneiss. It is usually a triple silicate of alumina, soda and lime. Carbonic acid of rain water unites with the soda and the lime, making carbonate of soda (washing soda) and carbonate of lime (the material of limestone), leaving the silicate of alumina, the chief ingredient of clay, as before. Carbonate of soda is very common in volcanic regions. Should it encounter nitric acid in rain water it becomes sodium nitrate, a very important plant fertilizer; if it meets hydrochloric acid it becomes sodium chlorid or common salt, so abundant in the ocean and in salt lakes. The carbonate of lime has also a very important history, and is very acceptable to some plants and many animals for use in their supporting hard parts.

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Carbonate of lime can not stay in solution in water unless there is an excess of carbonic acid present. Green plants use great quantities of this acid in elaborating their foods, such as the sugars, starch and the proteins, and hence water plants produce a scarcity of carbonic acid in the water, and consequently the lime carbonate is precipitated and they are buried in it, making much limestone. But where there are many water animals near by they relieve the plants of the carbonate of lime and use it for their skeletons, later to become limestone. In this way are produced shell beds, crinoidal limestone, fine chalk like that of England, France and western Kansas, and coarse chalk like that quarried at Cottonwood Falls, coral rock, and common limestone made of calcareous mud derived from any or all the preceding.

Some of the quartz of granitic rocks is dissolved in water containing alkali, from which it is removed in several interesting ways. Certain rhizopods, sponges and the diatoms use it in making their skeletons. Hot alkaline water will drop silica on cooling, as in the overflow of geysers. A very interesting form of deposition occurs wherever the alkaline water of lakes, ponds and rivers holding silica in solution encounters organic acids derived from the decaying bodies of plants and animals. In this way great quantities of wood in Kansas and elsewhere have become petrified (silicified), and cavities have been filled with flint, as in the Mississippian limestone (together with zinc and lead sulfids), and in the Wreford (Flint Hills) limestone and in other limestones of the state.

Before all the strata of the Mississippian period were laid down in Missouri, Kansas and Oklahoma, the earth forces proceeded to squeeze up the Ozarks and the Wichita, Arbuckle and neighboring mountains of Oklahoma to an altitude commensurate with the earth's needs and thus made dry land again in eastern Kansas and Oklahoma. How many thousand years eastern Kansas continued dry we do not know, but we do know that certain readjustments which always attend mountain-making resulted in the downfall of the crust between the Ozarks and the Arbuckle and Wichita mountains. Indeed, in eastern Oklahoma, beneath where the Arkansas river now flows, the crust sank more than a mile, involving eastern Kansas in the downthrow. This breakdown did not occur suddenly or continuously, but was accomplished during

some thousands of years. The downward movement was slow enough for the mountains to yield enough clay and sand, mostly clay, to fill the basin nearly as fast as the bottom sank. This deposit became the Cherokee shales and sandstone. Long before the Cherokee shales were all laid down, swampy places existed here and there in eastern Kansas and in eastern Oklahoma, which continued to grow swamp vegetation long enough to make all the peat for all the coal now mined at McAlester, Weir City and Lansing. Nor is this all, for in the sandy places, in the shale, enormous quantities of petroleum and natural gas accumulated, which either originated in the decaying bodies of plants and animals under the sand beds, or poured up through fissures in the bottom of the trough from deep in the interior of the earth, no one is certain which. This great synclinal trough must be still sinking, at least the stress on the strata of shale which filled the syncline is not fully relieved, for bottom shale in the McAlister coal mine buckles up here and there to the great alarm of the miners.

For four million years after the deposition of the Cherokee shales the eastern third of Kansas changed its physical geography scores of times, with the shore line much of the time in Missouri and Oklahoma. Scores of times the ocean would be free from clay, and layers of limestone would be laid down, made from the skeletons of plants and animals; then the seas would be deep and muddy and shales would accumulate, or the shore line would advance westward and sand for sandstone would spread over the southern and eastern portions of the state. At times sweet water swamps would exist long enough for peat to form, later to be buried, and finally to become beds of coal such as the Osage bed in Osage county and many others in eastern Kansas. These alternations were repeated so many times that a list of the more important strata would comprise more than fifty names, but every millennium saw some substantial gain, for the shore line was pushed westward nearly one-third across the state when the fourth great time of mountain-making came which drove the ocean permanently from the eastern half of the continent.

WHEN THE APPALACHIAN MOUNTAINS WERE MADE.

The fourth great period of mountain-making, the Appalachian revolution, completed the Appalachian system of mountains, elevated somewhat and permanently established the

Ozarks, Arbuckle and Wichita mountains, and probably elevated some of the ranges of the Rocky Mountains above the level of the sea.

About this time middle Kansas experienced the greatest drouth of its history. The water of several great interior seas evaporated, the basins were filled with salt water, the water again evaporated, the basins were filled again with salt water, the water once more evaporated—this process being repeated till hundreds of feet in thickness of rock salt accumulated, and many feet of gypsum, in deposits which extend from Kingman to Kanopolis. Next, all that remained of the Kansas-Oklahoma basin was filled with sand and some gypsum, probably from the Wichita mountains and some mountains in Colorado and New Mexico, and the work of the Paleozoic era in Kansas was completed.

THE AGE OF REPTILES.

For more than four million years Kansas was as level as Iowa is to-day, and as free from ocean water. Reptiles fought in her swamps and rivers and cycads dominated in her forests. The life of the coal period had largely vanished. Ferns continued in the swampy places, but the great lepidodendrons, sigillaria and calamites, whose fossilized trunks we find in eastern Kansas, are represented by very different descendants. The amphibians of the coal swamps of the preceding period had likewise changed to adapt themselves to new conditions. The ocean life, also, kept pace with the land life in a general advance to higher structures.

This Jura-Trias period of three and one-half million years closed in America with the fifth period of mountain-making, this time on the Pacific side. The Sierras, Cascades and several ranges of the Rocky Mountain region were squeezed above sea level.

For many thousand years after the close of this period of mountain-making the entire plains belt from North Dakota to Texas was covered with a sea of shifting sand that must have drifted from the old Rocky Mountains. This sand became cemented into a sandstone known as the Dakota.

The Cretaceous system of rocks in Kansas, of which the Dakota sandstone is the first member, consists of the usual alternation of shale, sandstone and limestone, all salt-water formations except the Dakota. The shales associated with the

Dakota contain much salt and gypsum and a bed of lignite. Part of the limestone of the Cretaceous is composed of the shells of rhizopods and is a chalk of the same age as the chalk of England and France. The life of this period is quite modern. Flowering plants, nectar-loving insects, bony fish, reptilian birds and reptilian mammals had been developed from the lower forms of life which preceded them. Among the fossil leaves found in the Cretaceous of Kansas are those of the tulip tree, willow, maple, sassafras, walnut, sequoia and fig. The fruits of the last two have been found well preserved. Reptiles, however, continued to be the dominant type of life.

At the close of the Cretaceous many of the western mountains were rejuvenated and the western half of the continent emerged from the ocean with nearly the present outline, but with much less elevation. Great interior seas occupied the basins throughout the western interior and received the abundant sediments from the mountains.

THE AGE OF MAMMALS.

The Tertiary period followed the Cretaceous and is noted for the reign of mammals and the rise of the Rocky Mountains. At first the drainage of Kansas was westward into the interior seas, but later in this period with the rise of the Rocky Mountains the slope was reversed and the drainage as we know it to-day became established. The mountains slowly increased their elevation for more than a million years, and the crushed and metamorphosed strata yielded readily to the combined action of the wind, rain and carbonic acid. The high gradient produced by the rise of the Rocky Mountain plateau to an elevation finally exceeding three miles enabled the torrents of rain water which fell at that time to spread coarse and fine debris over the entire plains region as far eastward as central Kansas and Nebraska. The sediments with which western Kansas was flooded at that time consisted of gravel four and five inches in diameter, grading down to fine sand. The pebbles represented the common rock species of the Rocky Mountains. In the list are pebbles of granite, syenite, porphyry, rhyolite and basalt, not yet disintegrated, and polished pebbles of quartz. Great lakes occupied the plains of western Kansas and received this debris. As their basins filled, the sediments became on the whole finer and constitute the surface soils in that part of the state.

The gravel layers have furnished an excellent channel for a subsurface flow from the mountains of surplus waters, and are the source of the invaluable sheet water of the western part of Kansas and neighboring states. The Staked Plains are underlaid by the same stratum of Tertiary gravel, and thousands of acres are now irrigated with water from wells that penetrate this source of water supply.

Among the strange mammals which roamed the plains of Kansas were camels, mastodons, three-toed horses, rhinoceroses, saber-tooth tigers and wolves, but man had not yet appeared.

THE AGE OF ICE AND OF MAN.

By the close of the Tertiary and the opening of the Quaternary periods the great interior seas were much smaller, and many of them were completely filled with sediment. The forms of life became more nearly what we find in Kansas to-day. Early in the new period the climate became so cold that finally the snow stayed on the ground summer as well as winter, and the great Kansan glacier pushed into the state from the north as far as the Kaw and Big Blue rivers and a little farther. This glacier, as do all others in a plains region, pushed the hills into the valleys, dug deeper into the soft shales than into the hard limestones, and shoved great quantities of northland bowlders and gravel into southern latitudes. The limestone in Nemaha county shows the planing work of glaciers, and the hills south of Topeka are full of quartzite and granite bowlders from Minnesota and South Dakota.

While the glaciers were still plowing the northern states man made his appearance, whether in Europe first, in Asia, Africa, or America, no one knows; but of this we are sure, he dominated the world when he made his entrance in it. He soon became intensely interested in flocks and herds, in crops and soils, and in forests and rainfall. Wherever these are directly influenced by the geological development of Kansas, we shall find material for profitable study. Therefore with soils and water supply this paper must close.

THE SOILS, SUBSOILS AND CROPS.

As explained in the preceding pages, Kansas owes the clays, sands and calcite of her shales, sandstones and limestones, respectively, first, to the disintegrating granites and lavas of the Ozarks and Oklahoma mountains; second, to the floods that

shifted enormous amounts of debris from the crushed strata of the earth's crust pushed up in the Rocky Mountains; third, to the disintegration of the miscellaneous assortment of bowlders, gravel and finer drift pushed into Kansas from the states north, by the Kansan glacier; and lastly, to the myriads of plants and animals that have used the calcium carbonate and silica in solution for their skeletons, and then in the course of nature laid down their skeletons in beds of limestone.

Then, in turn, the shales, sandstones and limestones disintegrated where exposed to air and rain, and the various subsoils were formed. The relationship is so close between the subsoil and the underlying shale, sandstone or limestone, except where running water or the wind has shifted the subsoil, that a map showing the shales, sandstones and limestones of the state serves equally well for a map of clay subsoils, sandy subsoils or calcareous subsoils. The overlying soils differ from the subsoils chiefly in the possession of humus, without which no crop, except some of the legumes, will mature. The fourth visible essential of soils and subsoils is water, and the relationship between water and all growing vegetation is so intimate that tillage is chiefly concerned in conserving the water supply. The fifth essential of a productive soil and subsoil is porosity, that air may circulate freely about the roots of plants. The best soils and subsoils, then, must be composed of clay and sand to give consistency and penetrability, and of humus to conserve air and water and to serve as food for bacteria.

KANSAS SOILS.

The proper admixture of clay, sand and humus determines the physical qualities of a fertile soil; but these ingredients may be present in best proportions and the soil remain unproductive. Certain chemicals must be present and be in solution in water or not a plant will grow. The following compounds serve two great purposes in the plant economy: 1. Water, carbon dioxide, and the nitrates, sulphates and phosphates furnish the chemical elements used in food elaboration. 2. Compounds containing potash, iron, lime and magnesia together with common salt and silica are necessary in the chemical physiological processes, but are not found in plant foods.

These minerals so essential to the continued existence of plants and animals on the earth come directly or indirectly from subjacent or neighboring rocks. As has been stated,

clay is derived from shales, slates, granites and lavas; quartz sand comes from disintegrated sandstones and granites and from pulverized quartzites; potash is taken from the feldspar of granite, and soda and lime from the feldspar of lava.

Potash, soda and lime were taken away by carbonic acid and exist in the waters as carbonates or bicarbonates; but the carbonic acid will vacate in favor of almost any other acid. Carbonate of potash becomes nitrate of potash in the presence of nitric acid generated by bacteria or by flashes of lightning in thunderstorms. The carbonate of soda, so abundant in lakes in the craters of volcanoes, may be changed to a nitrate on encountering nitric acid, or to chloride (common salt) in the presence of hydrochloric acid. In a similar way potash carbonate may become a chloride.

The bicarbonate of lime in rivers, lakes and ocean is used in skeleton-making by myriads of animals, which, however, reject half of the carbonic acid. Great quantities of the bicarbonate of lime are precipitated as a carbonate by sea weeds which rob it of half of its carbonic acid.

The sulphates are among our most abundant minerals. The plants and animals of Kansas will never suffer from lack of sulphur so long as gypsum (lime sulphate plus water) is such a common mineral, and epsom salts (magnesium sulphate) is so generally present in spring water.

Phosphatic minerals are fortunately widely distributed in the crust of the earth, especially the mineral apatite (in tricalcium phosphate). Chemists say that nine one-hundredths of one per cent of the crust of the earth is phosphorus. From the first, life has found phosphorus indispensable as an ingredient of its protoplasm, and no soil will produce crops without it. All sedimentary rocks in Kansas contain small amounts of this element and on disintegration yield it to the soils and subsoils. The amounts are very small and must be expressed in hundredths of one per cent. Sandstone has about seven, shale about seventeen, and limestone, not weathered, forty-two. As an argument in favor of deep plowing it must be remembered that the subsoils are richer in phosphorus than the soils because of leaching.

Potash is necessary, in some way not well understood, to plants in their work of food-making, and where lost to soils by leaching must be supplied in a fertilizer. The other minerals listed above are necessary to the work of plants but are

supplied by our rocks in such quantities that plants are not likely to suffer from a lack of them. To this statement there is one important exception: Water is necessary and the supply is scanty, in all the state sometimes and in part of the state all the time.

THE CONSERVATION OF WATER.

In spite of its scarcity at times and in places it is evident that water has played the leading part in the geological development of Kansas, and in the industrial development as well. It is fitting, therefore, that the paper should conclude with a brief discussion of water supply and how it may be best conserved. The estimates given below are adapted to Kansas from some statistics quoted by President C. R. Van Hise in his book, "The Conservation of Natural Resources of the United States."

The annual rainfall of Kansas totals on the average thirty-seven and one-half cubic miles. Of this amount about one-half, eighteen and three-fourths cubic miles, flies off very soon after a rain into the air (by evaporation). Six and one-fourth cubic miles are consumed by plants, or sink very deeply into the earth, so far that they do not get back again except through volcanoes. At any rate, they are lost to the statistician. One-third, or twelve and one-half cubic miles, runs off directly or sinks into the ground and feeds springs and rivers by seepage. Possibly one or two cubic miles of this ten run off at the surface and make Kansas floods, and the balance flows slowly through the ground to the rivers and keeps them going between rains. Many in times past have believed that wells are fed from near-by rivers, but careful experiments have shown that water in wells near streams stands higher than it does in the stream and that the ground-water flows towards the watercourse. This is true at all times except when heavy rains towards the source of the river cause temporary flood, when the reverse is true.

Below this shifting surface water, to a depth of seven miles, are forty times as much more, or twelve hundred cubic miles of water under Kansas, which flow slowly back and forth, up and down, or in a circle, deep in the crust of the earth, distributing and concentrating the ores and other minerals.

All these forms of water present to the observer interesting material for study, but the run-off of ten cubic miles of water, rich in all the minerals that plants and animals need, demands

immediate study into ways and means for preventing this waste. Obviously, if the water can be kept on the land where it fell as rain, most of the waste of soil fertility will be prevented. Two ways of doing this will be stated very briefly.

One, that of constructing dams for reservoirs to keep the water away from the rivers as long as possible, is already practiced by our wisest farmers. Forests on the hillside serve the same purpose. Both methods conserve stock water, and timber as well.

The second plan consists in opening up the soil and subsoil very deeply, so as to make a reservoir of the fields. This plan is also practiced by wise farmers, especially where rainfall is scanty. The rainfall of two years is made to serve the crops of one year. The one harvest is more than twice as bountiful in the dry belt as two harvests where the old plan of a yearly crop is followed.

With water properly conserved, rains will increase their value to the people of Kansas, costly gullies and small creeks will disappear, and the surface of the state will approach a stability long absent from her borders. Man's kingship of the earth will consist in the scientific mastery of his environment, and not in the haphazard mastery so long practiced. This scientific mastery must come, if it come at all, through a thoughtful study of the geological development of the state, given point by making such a study terminate in the present condition and needs of the entire state. Man can not be truly happy, he can not be truly prosperous, till he forgets what seem to him to be his immediate personal interests, and works for the good of all. When he does this he will strive earnestly to conserve soil, rainfall, plants, including forests, the useful lower animals, and the human race.